UTILITY SCALE
BATTERIES

BURNS & McDONNELL

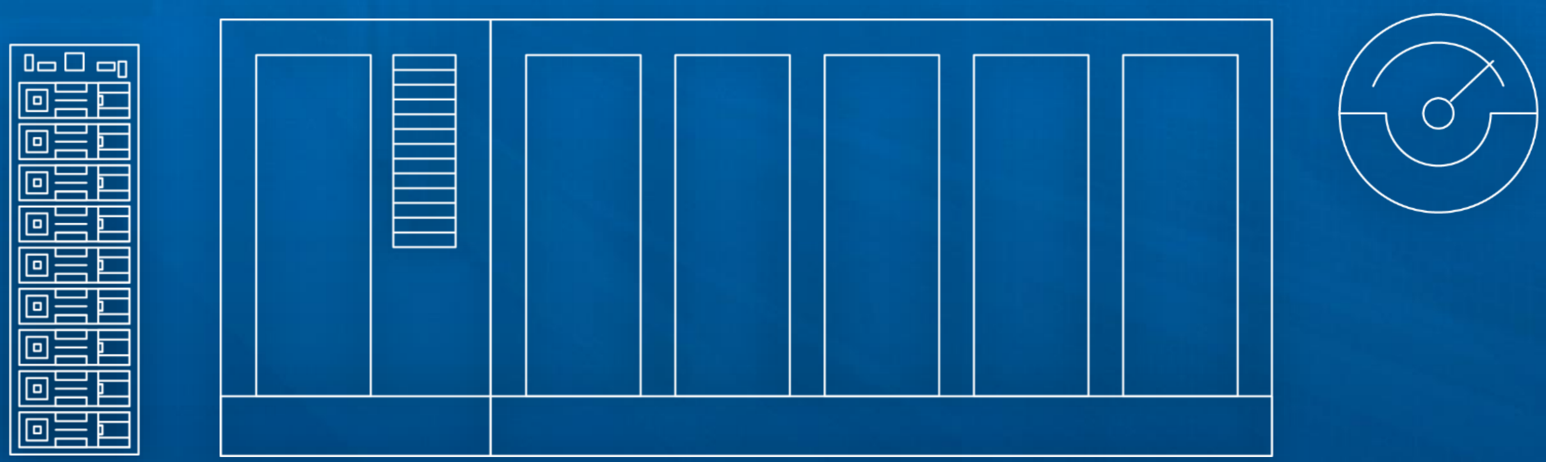
Kansas Energy Conference | Oct 2018

SAFETY MOMENT

Battery Safety

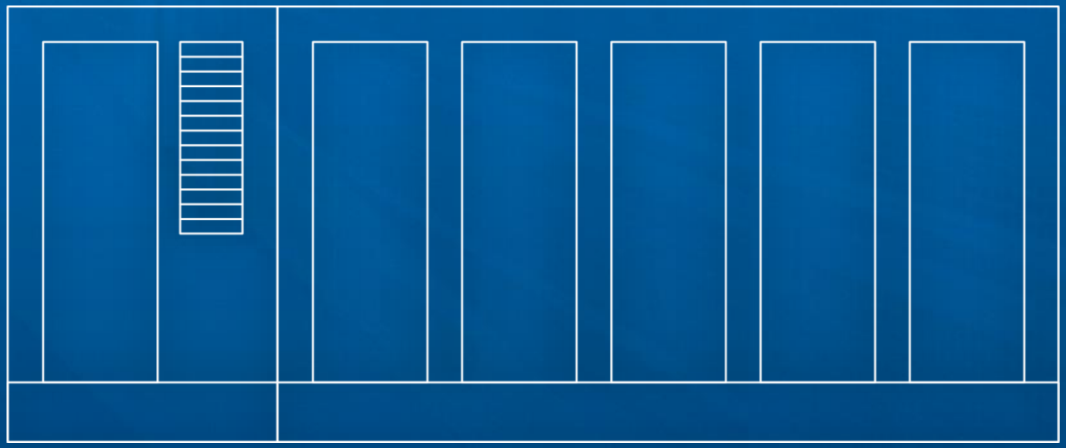
5640 A x **40** = **255 kA**

5640 A	x	40	=	255 kA
Short Circuit Current Per Rack		Racks Per Container		Short Circuit Current Per Container



Battery Safety

5640 A Short Circuit Current Per Rack **x** **40** Racks Per Container **=** **80** Pounds Dynamite



BATTERY OVERVIEW

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Energy Storage Technologies

Mechanical

- Pumped hydro
- CAES
- Flywheel
- LAES (liquid air energy storage)

Electromechanical

- Traditional batteries
- Flow batteries
- Lithium ion

Thermal

- Sensible - Molten salt, chilled water
- Latent – ice storage
- Thermochemical storage

Electrical

- Supercapacitors
- Superconducting magnetic energy storage

Chemical (Hydrogen

- Power-to-power (fuel cells, etc)
- Power-to-gas

Lithium Ion – Many Varieties

NMC

Preferred for
EV market

LFP ($LiFePO_4$)

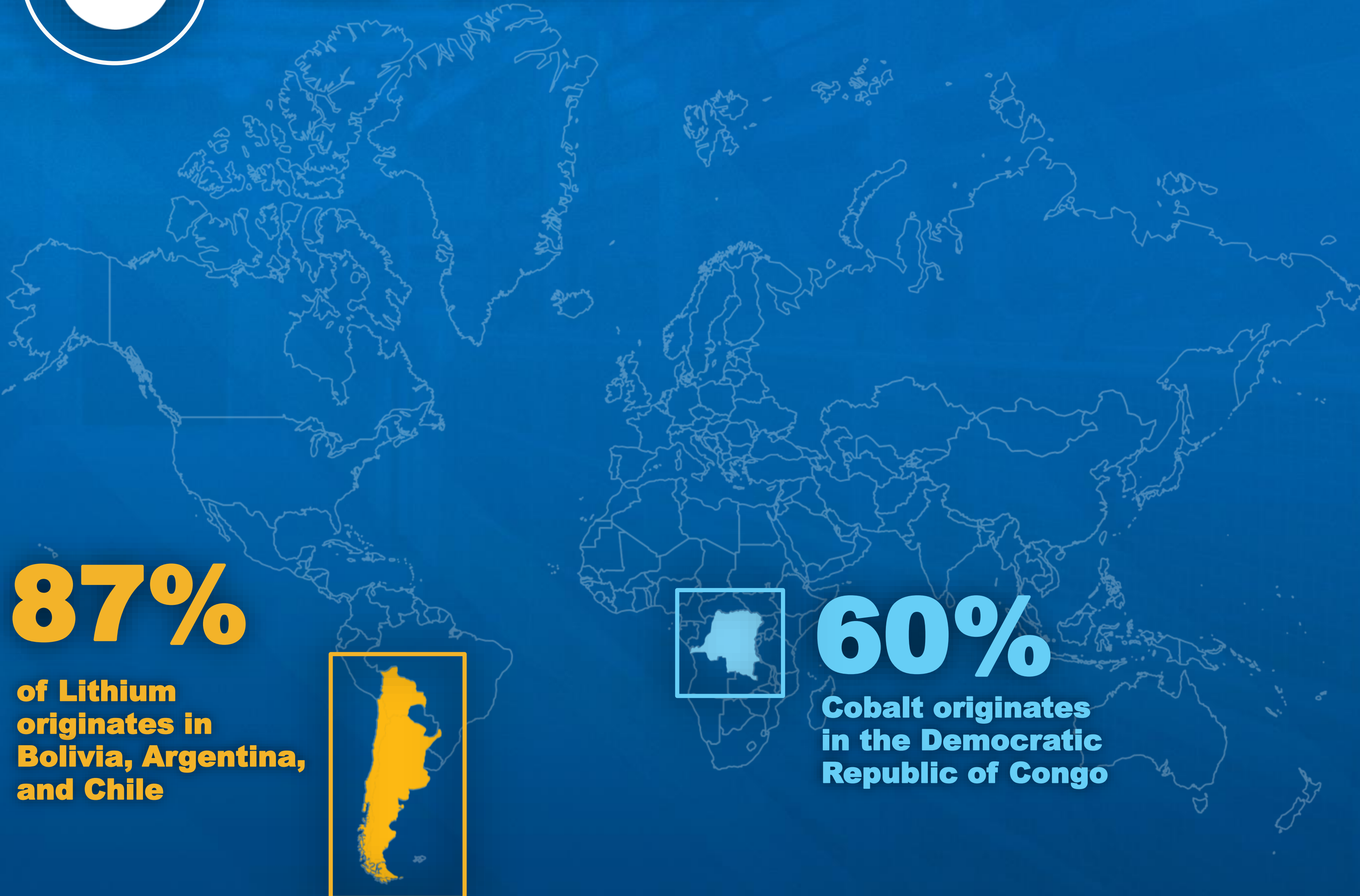
Excellent Safety
Moderate energy
Low Power

NCA

High energy
High power
Good life
High Cost
Marginal Safety

Lithium | Cobalt | Manganese | Nickel | Phosphate | Iron | Aluminum

Material Sources



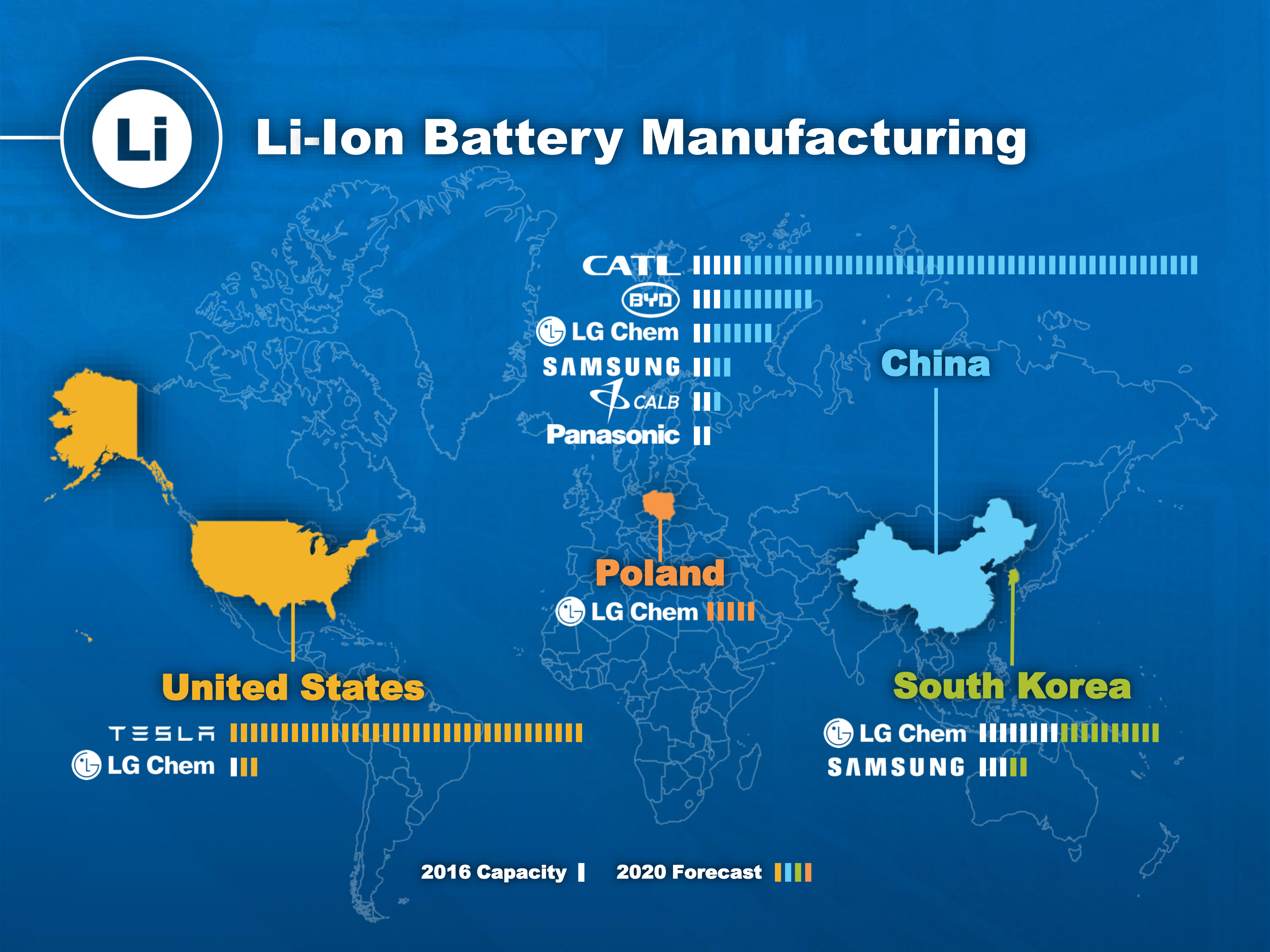
87%

of Lithium originates in Bolivia, Argentina, and Chile

60%

Cobalt originates in the Democratic Republic of Congo

Li-Ion Battery Material Cost Trends

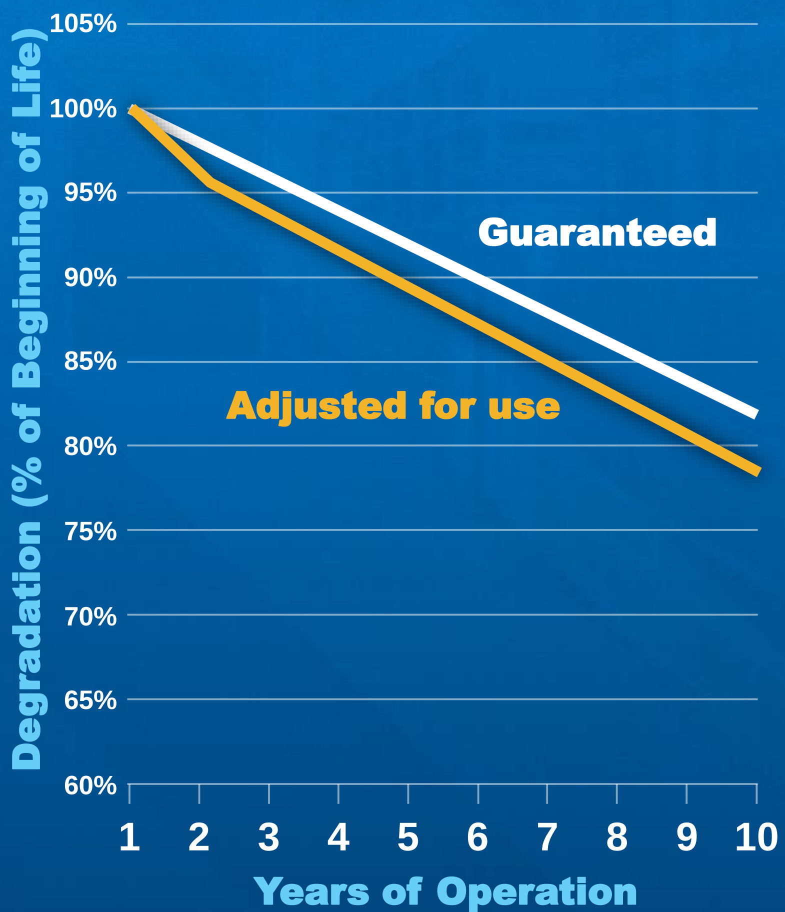


Li
Li-Ion Battery Manufacturing
CATL
BYD
LG Chem
SAMSUNG
CALB
Panasonic
China
Poland
LG Chem
United States
TESLA
LG Chem
South Korea
LG Chem
SAMSUNG
2016 Capacity
2020 Forecast

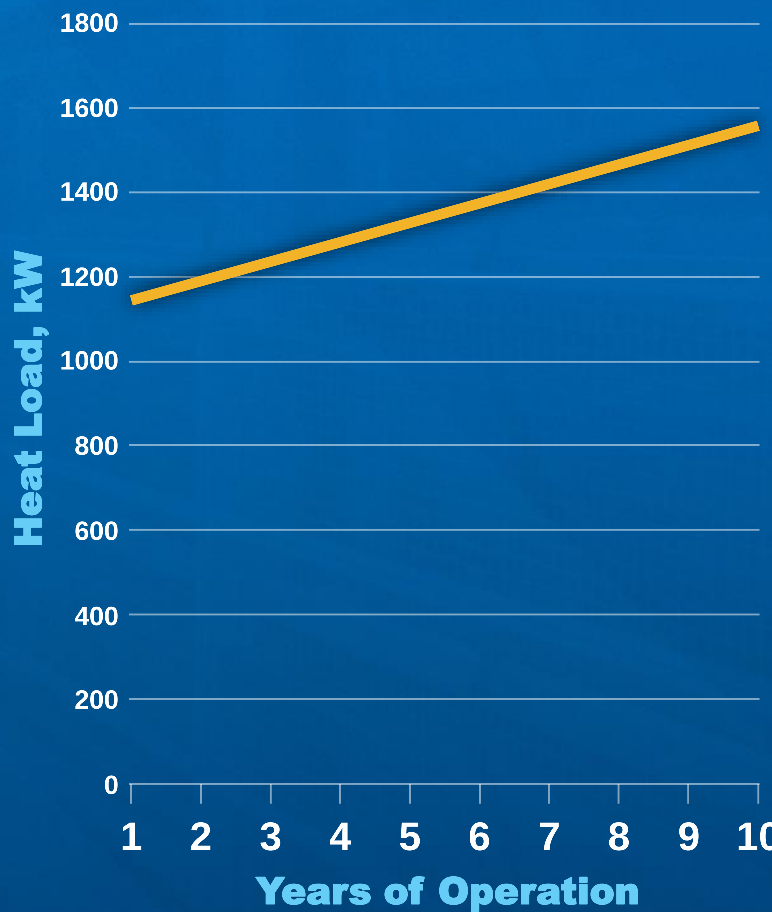
50MW, 200MWh Building

Designing a Battery System

Degradation



Increasing Heat Load

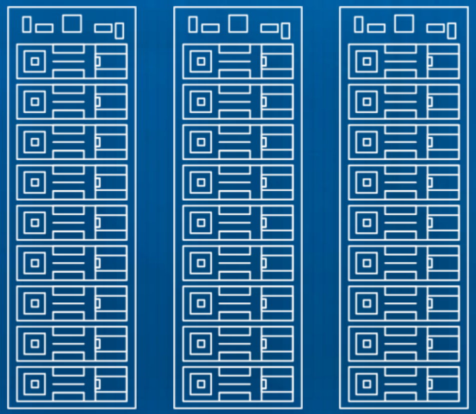


Designing a Battery System

Maintaining Capacity

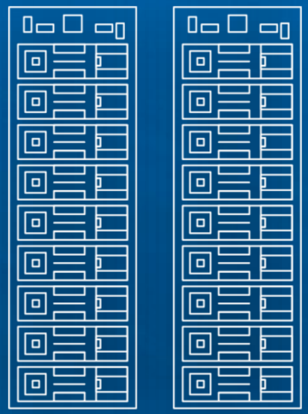
5 Year

Base Capacity



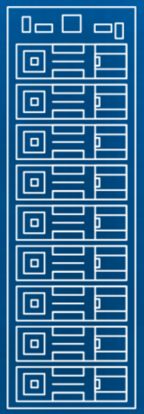
10 MWh

Overbuild



2.5 MWh

Augment



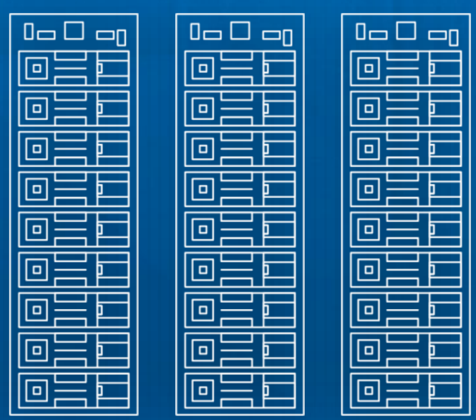
1.0 MWh

Designing a Battery System

Maintaining Capacity

15 Year

Base Capacity

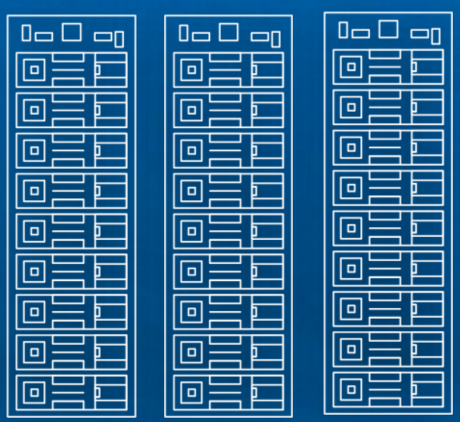


10 MWh

Overbuild

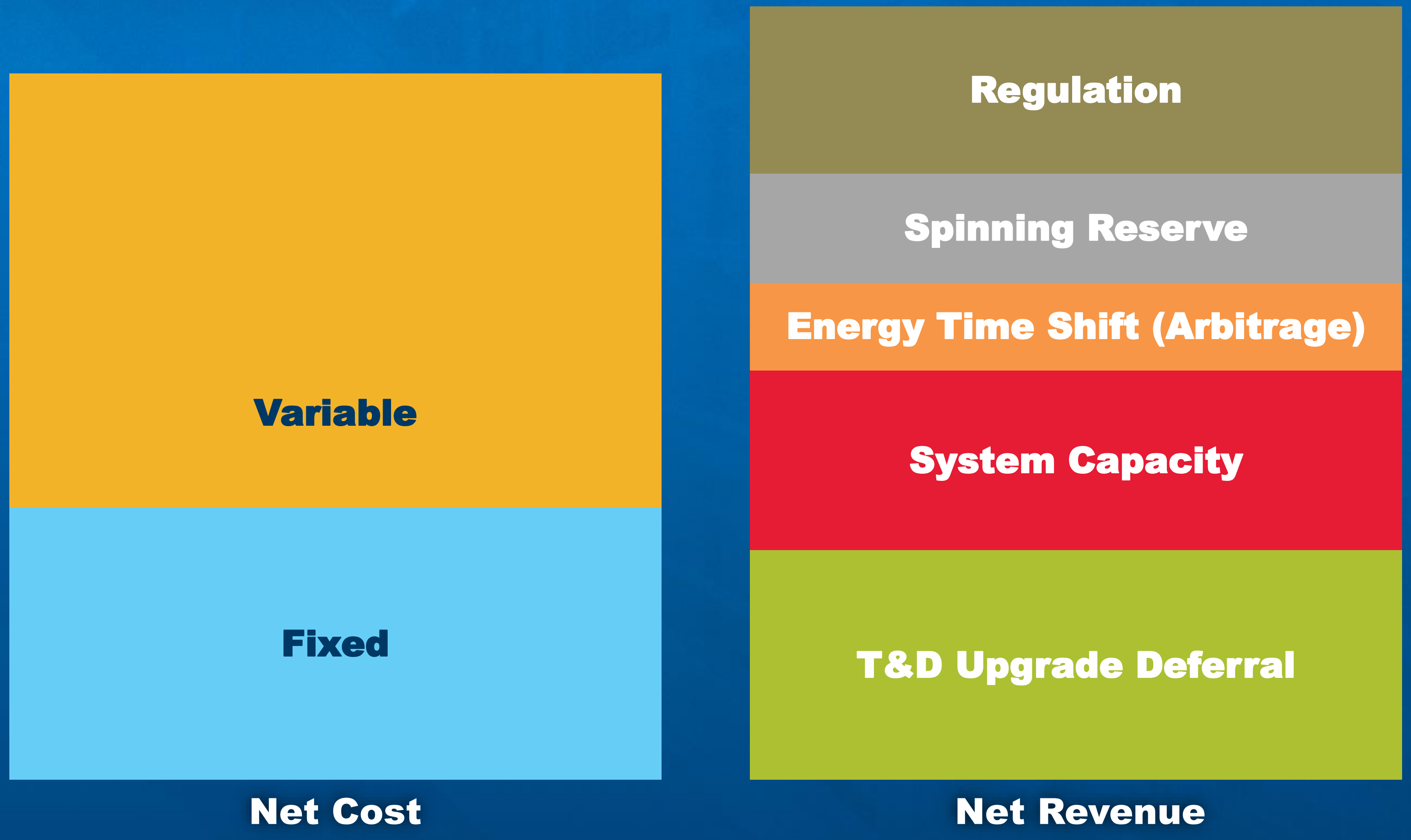
1.5 MWh

Augment



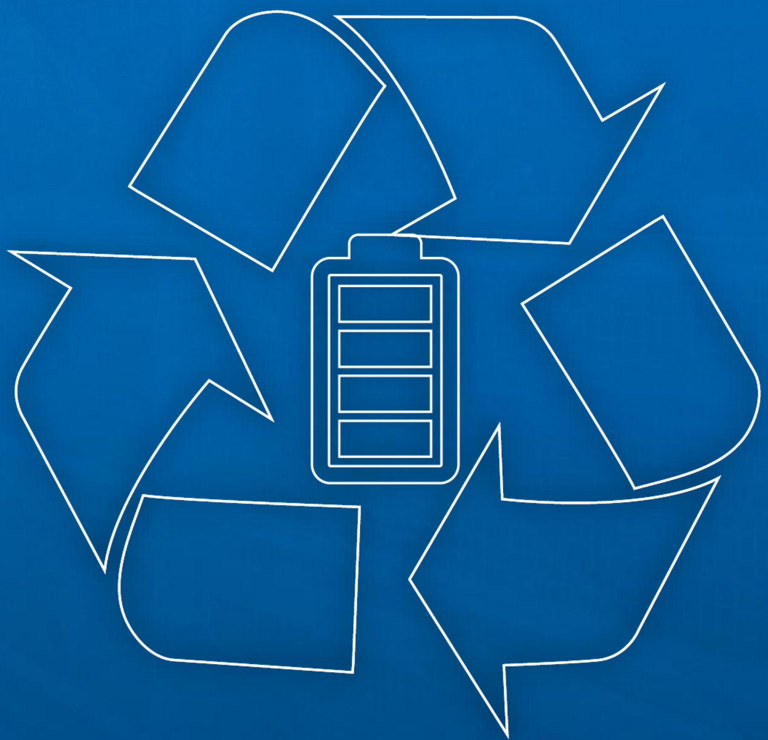
3 MWh

Justifying Energy Storage



BESS – End of Life

- Can **technically recycle 80%** of Li-Ion battery
- Federal law does not mandate recycling of spent lithium-ion cells
- No economically viable recycling program exists
- **Utility can pay extra** to have them reduced to lower grade
- Increased demand, geopolitical unrest, societal pressures, technology advancements may change dynamics



BATTERY TECHNOLOGY

WHAT'S NEXT

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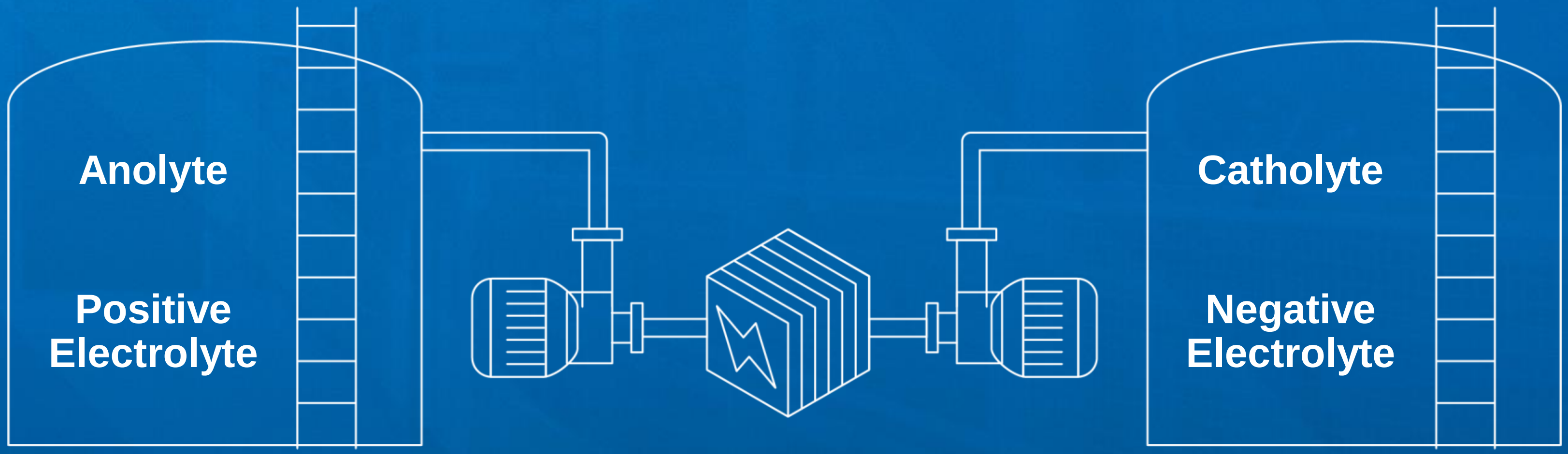
Flow Batteries



Reaction Cell and Membrane

Flow vs. Li-Ion Comparison

Technology	Fixed O&M	Calendar Degradation Fixed Fee	Cycling Degradation Variable Fee	Charging Costs
Li-Ion	Low Preventative Maintenance	State-of-Charge Dependent	High; Module Replacement	85% RTE
Flow	Moderate Preventative Maintenance	No Degradation	No Degradation	70% RTE

Flow vs Li-Ion Cost Comparison